Department of Geodetic Science

DATA ANALYSIS IN CONNECTION WITH THE NATIONAL GEODETIC SATELLITE PROGRAM (II)

First Semiannual Status Report

Period Covered: August, 1967 - January, 1968
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Prepared for

National Aeronautics and Space Administration
Washington, D. C. 20546

The Ohio State University
Research Foundation
Columbus, Ohio 43212

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PREFACE

This project is under the supervision of Ivan I. Mueller, Professor of the Department of Geodetic Science at The Ohio State University, and it is under the technical direction of Jerome D. Rosenberg, Project Manager, Geodetic Satellites Program, NASA Headquarters, Washington, D. C. The contract is administered by the Office of University Affairs, NASA, Washington, D. C. 20546.

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2. ACCOMPLISHMENTS DURING THE REPORT PERIOD

2.1 Task No. 1 — Extension of Computer Programs

The purpose of this project is to establish an adjustment process for such observed quantities as dr/dt, i. e., the range rate, determined by use of Doppler shifts of a radio signal.

The range differences Δr could be obtained by numerical integration, quantities that may eventually enter into adjustment instead of dr/dt. This possibility is investigated, together with its advantages, disadvantages and applications.

After eliminating the unnecessary parameters from the normal equations, corrections of ground stations' coordinates will be obtained in such a way as to combine them with the output of already existing adjustment programs for directions and ranges.

So far the work has been restricted to literature search and discussions on the various possibilities.

2.2 Task No. 2 — Preprocessing Electronic Observations

The work on this task is practically finished; a report should be submitted by early April.

2.3 Task No. 3 — Data Analysis for the NGSP

All available optical data in the Data Center has been requested. It is planned to use all this data in the near future.

Optical data processing is investigated in the following directions.

(1) In accordance with the resolution made at the meeting in Durham, each agency (USCGS, ACIC, SAO, GSFC) received plate measurements from three BC-4 plates. The reductions are expected to be in by February 15. Conclusions will be drawn subsequently.

(2) Photogrammetric and astrometric plate reduction techniques are being compared for accuracy.

(3) In accordance with the following outline, investigation is under way on how to best utilize the BC-4 passive satellite data in the Data Center in the existing format:

1. STATEMENT OF WORK

1.1 Primary Objective

The primary objective of the OSU investigation is the geometric analysis of geodetic satellite data. The analysis is accomplished in three steps:

(1) The establishment of a primary network where station positions are known to an internal consistency of approximately 10 meters or better to serve the following purposes: (a) unify the various geodetic datums in use around the world, (b) connect NASA tracking stations, isolated islands, navigational beacons, and other points of interest to the unified system.

(2) Establishment of a densification network where station positions are known to an internal consistency of approximately 3 meters or better to serve the following purposes: (a) improve the internal quality of existing geodetic systems (triangulation, etc.) by establishing "super" control points in sufficient number, (b) to provide control for mapping to scales as large as 1 : 24,000.

(3) Establishment of a set of scientific reference stations where positions are known to an accuracy of one meter or better with respect to the unified system for advanced applications.

1.2 Tasks for the Period 1967 - 1969

In order to fulfill the primary objective listed in section 1.1, the following tasks will be attempted during the current grant period.

(1) Extension of the computer programs for range and range rate, Doppler, and laser systems.

(2) Development of data preprocessing systems to handle the data from the above observations methods.

(3) Analysis of observational data for the National Geodetic Satellite Program for the purpose of fulfilling the primary objectives listed in section 1.1 as observational data becomes available.

(4) The development of computer programs for the adjustment of optical, ranging and Doppler data in the short-arc mode.

(5) Theoretical investigations into sequential least squares adjustment of simultaneous satellite observations in combination with terrestrial data.

I. General: Divide the satellite image trail on each plate into segments, each segment corresponding to a certain time period which is imaged by a specific number of satellite positions on each plate. Fit polynomials to each segment of the satellite image trail (degree 1 through 5).

   A. 90 image trails

   B. 60 image trails

   C. 30 image trails (depending on results of A and B)

   D. Tests: Do test to determine the degree polynomial required to describe the shorter trails (F-test).

II. Select a time near the center of each satellite trail segment that is imaged on all three plates.

   A. Compute a fictitious point on each polynomial corresponding to this time:

      1. Compute the variance of the fictitious point:

         a) compare it for the different degree polynomials

         b) compare it for different number of images in the trail

      2. Compare the variance of the fictitious points to those obtained by the USCGS for their one fictitious point.

   B. Use the polynomials of the USCGS to compute X/Y coordinates of the same fictitious points selected in II A above.

      1. Compare the computed X/Y coordinates to those obtained in II A.

      2. Compute the variance of these points and compare with those obtained in II A 1.

III. Do one or more astrometric reductions for the images corresponding to times chosen in II above:

   A. Compute direction to the satellite image (or right ascension/declination).

   B. Compare to those obtained in II.

Possible Routes:

IV. Simplified photogrammetric approach to smaller areas of plate.

V. USCGS reduction for smaller areas of plate (let them run the program).

VI. Short-arc method.

Questions to be answered:

(1) How independent are observations from the same plate using the same plate constants?

(2) How independent are observations from same plate with different plate constants?

(3) How to best compare results from the different methods.

(4) Problem of requirement for simultaneous observation in the geometric methods.

The fact that the SECOR data (23 passes) in the Data Center is being replaced by correct data is happily acknowledged. Once this data is in, together with the other promised (some 200 passes) SECOR data, it will be requested and used at once.

2.4 Task No. 4 — Short-Arc Orbit Constraint Adjustment for Satellite Observations

The present effort on this task began on September 27, 1967, and was based on the previously reported investigations of Dr. Richard Rapp and Mr. John Snowden. After an initial period of planning, coding of a FORTRAN IV computer program began in the first week of November. Several new features in program flexibility, computational efficiency, and completeness of mathematical expression were added to the previously reported computer program in the translation from the SCATRAN language to FORTRAN IV. Coding was completed by the beginning of December, and by the end of December the program was debugged and returned satisfactory answers. To increase the significance of the adjustment, all computations which lead to the formation of the (observed-computed) discrepancies were converted to double-precision. This conversion was completed and debugged by the end of January, 1968.

In its present state, the program accepts topocentric direction and range observations, or any mixture of the two. There is no limit to the number of observations per orbit or the number of orbits which may be handled. The program will form normal equations for a net of up to 150 stations, but in its present form proceeds to a solution only if the number of stations is 30 or less.

The orbit is characterized by empirical expressions for the mean Keplerian elements of the form used by the Smithsonian Astrophysical Observatory. Of the 30 parameters which characterize the elements of a given orbit, any subset of 21 or less may be considered unknown in any run of the program.

Consideration of nutation and polar motion is fully included. The program makes provision for weighting of observations, including the possibility of co-variance between right ascension and declination observations, and allows for a priori weighting of station coordinates. In its present form, the program is composed of 5 links under the IBJOB overlay system for the IBM 7094.

The data used for program debugging consists of errorless generated direction observations from 5 stations to a single orbit over a time span of 3 days. The orbit used has a small eccentricity (0.00715), and our tests indicate that the direction observations achieve very poor separation of the mean anomaly and the argument of perigee for this orbit. The numerical effect of this poor separation is poor conditioning of the normal equations so that it may be necessary to use double precision computations in the solution.

2.5 Task No. 5 — Sequential Least Squares Adjustment of Satellite Triangulation and Trilateration in Combination with Terrestrial Data

The mathematical models relating the unknown parameters (ground station and satellite position coordinates, and datum shift components) to the observables have been formulated and linearized. The main observables consist of topocentric right ascensions and declinations and topocentric ranges; observables of secondary importance include absolute terrestrial spatial distances, deflection of the vertical components, geoid undulations, orthometric heights, astronomic coordinates, and others.

The ground matrix equations for the sequential least squares adjustment of the particular problem at hand have been derived. The detailed equations needed for programming are near completion.

Programming is well under way. The system now consists of six segments in which optical and range normal equations are formed, added, and solved. Peripheral information such as event plots, standard deviations and associated item plots, and contouring of the correlation coefficient matrix are also an integral part of the system.

The next step is to include an additional segment which will be capable of the sequential modification of an original solution due to additional terrestrial and satellite observables.

3. PERSONNEL

Ivan I. Mueller, Project Supervisor, part time

Edward J. Krakiwsky, Research Associate, part time

Georges Blaha, Research Associate, part time

James P. Reilly, Research Assistant, part time

Charles R. Schwarz, Research Assistant, part time

Daniel Hornbarger, Research Assistant, without compensation

James Veach, Research Assistant, without compensation

Joseph E. Gross, III, Research Assistant, without compensation

Jeanne C. Preston, Research Aide, full time

Irene G. Bayorek, Technical Assistant, part time

John R. Miller, Research Aide, part time

Michael R. Kowalysko, Research Aide, part time

Christine L. Jaeger, Technical Assistant, part time

4. TRAVEL

Trips made by project personnel during the report period are:

Ivan I. Mueller, Lucerne, Switzerland, September 20 - October 5, 1967
to attend XIVth General Assembly of the International Union of Geodesy and Geophysics

Joseph E. Gross, Washington, D.C., September 11 -20, 1967
to visit various agencies in and round Washington to investigate their procedures of preprocessing electronic satellite data

Joseph E. Gross, Boston, November 12-13, 1967
to obtain information about preprocessing satellite data at the Smithsonian Astrophysical Observatory

Ivan I. Mueller, Washington, D.C., December 12-14, 1967
to attend GEOS Program Review Meeting at NASA Headquarters

James P. Reilly, Greenbelt, Maryland, December 18-19, 1967
to visit the Geodetic Data Center at Goddard Space Flight Center